US009450526B2

(12) **United States Patent**
Hirata

(10) **Patent No.: US 9,450,526 B2**
(45) **Date of Patent: Sep. 20, 2016**

(54) **IMAGE FORMING APPARATUS, METHOD OF CONTROLLING IMAGE FORMING APPARATUS, AND STORAGE MEDIUM**

(71) Applicant: **BROTHER KOGYO KABUSHIKI KAISHA**, Nagoya-shi, Aichi-ken (JP)

(72) Inventor: **Hironori Hirata**, Nagoya (JP)

(73) Assignee: **BROTHER KOGYO KABUSHIKI KAISHA**, Nagoya-Shi, Aichi-Ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/620,538**

(22) Filed: **Feb. 12, 2015**

(65) **Prior Publication Data**

US 2015/0236627 A1 Aug. 20, 2015

(30) **Foreign Application Priority Data**

Feb. 17, 2014 (JP) 2014-027321

(51) **Int. Cl.**

H02P 6/18	(2016.01)
H02P 6/20	(2016.01)
B41J 2/47	(2006.01)
H02P 6/16	(2016.01)

(52) **U.S. Cl.**

CPC ***H02P 6/181*** (2013.01); ***B41J 2/471*** (2013.01); ***H02P 6/16*** (2013.01); ***H02P 6/182*** (2013.01); ***H02P 6/20*** (2013.01)

(58) **Field of Classification Search**

CPC B41J 2/435; B41J 2/471; H02P 6/18; H02P 6/181; H02P 6/182; H02P 6/20; H02P 6/16

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,019,756	A	5/1991	Schwarz	
6,396,225	B1 *	5/2002	Wakui	H02P 6/085 318/400.01
6,476,370	B1	11/2002	Suzuki et al.	
7,327,378	B2 *	2/2008	Han	H02P 6/182 347/243
2002/0074968	A1	6/2002	Mitsuda	

(Continued)

FOREIGN PATENT DOCUMENTS

JP	6-284783	A	10/1994
JP	10-225079	A	8/1998

(Continued)

OTHER PUBLICATIONS

Office Action issued in related application JP 2009-088404, mailed Feb. 10, 2011.

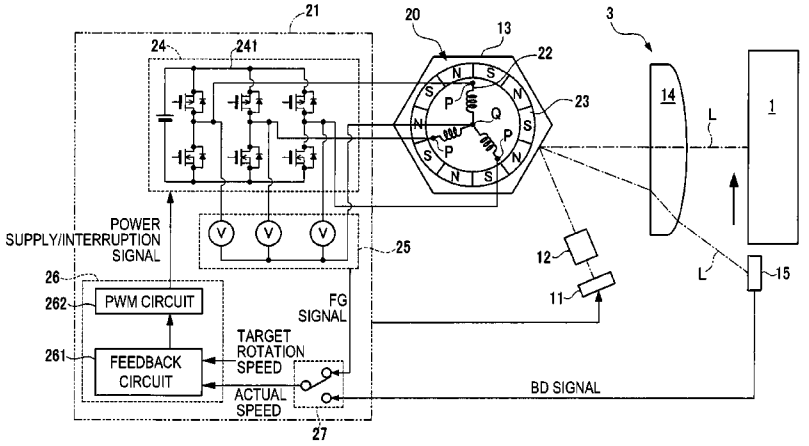
(Continued)

Primary Examiner — Sarah Al Hashimi
(74) *Attorney, Agent, or Firm* — Merchant & Gould P.C.

(57) **ABSTRACT**

An image forming apparatus includes: a light source; a polygon mirror; a brushless motor rotating a rotary polygon mirror; a light receiver configured to receive the light beam reflected by the polygon mirror; and a controller configured to perform driving control; detect a value related to an induced voltage; and perform a phase switching process. In a start-up period, the controller performs a control switching process of performing switching from rotation speed control based on the induced voltage to rotation speed control based on the light receiving timing of the light beam in a specific range in which a length from a start timing of an interruption period of the power to a timing when the detected value reaches the reference value does not become shorter than a length of a reference-disabled period.

23 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2003/0052633	A1	3/2003	Inagaki et al.	
2003/0107337	A1	6/2003	Kokami et al.	
2004/0207717	A1	10/2004	Han et al.	
2005/0281545	A1	12/2005	Sugimoto et al.	
2006/0139442	A1	6/2006	Kurita	
2006/0208179	A1	9/2006	Itami	
2009/0129017	A1	5/2009	Takada	
2010/0245521	A1	9/2010	Kubo	
2011/0242259	A1*	10/2011	Kubo	B41J 2/471 347/224

FOREIGN PATENT DOCUMENTS

JP	11-129538	A	5/1999
JP	11-222337	A	8/1999
JP	2000-316294	A	11/2000
JP	2001-174728	A	6/2001
JP	2003-189674	A	7/2003
JP	2004-326105	A	11/2004
JP	2007-62266	A	3/2007
JP	2007-236090	A	9/2007
JP	2007236090	A	9/2007
JP	2010-237622	A	10/2010

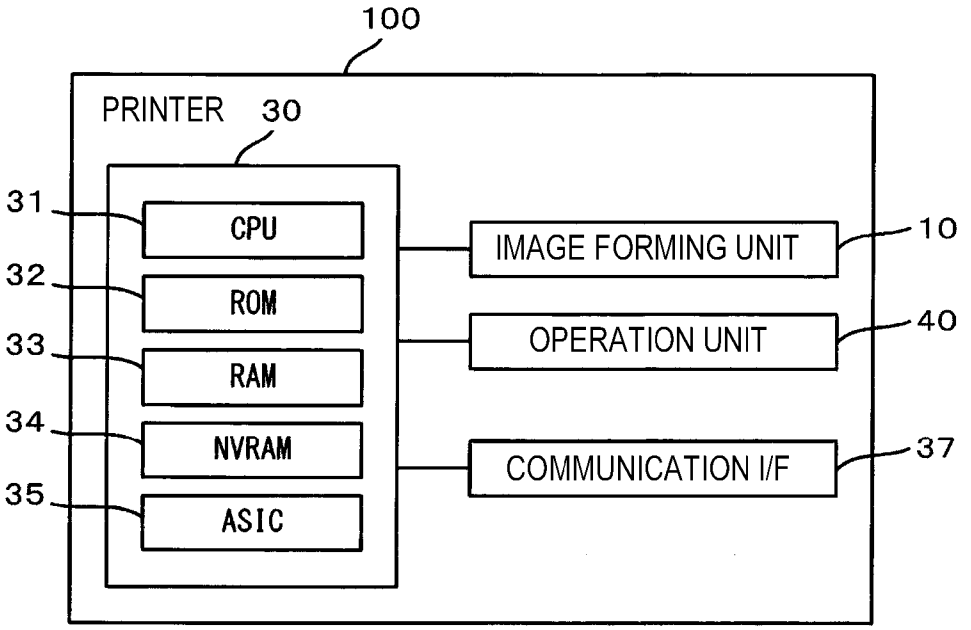
OTHER PUBLICATIONS

Extended European Search Report issued in related EP application 10002753.1, mailed Aug. 3, 2010.

Office Action issued in related U.S. Appl. No. 12/724,751, mailed Apr. 6, 2012.

* cited by examiner

FIG. 1


100
PRINTER
30
31
CPU
32
ROM
33
RAM
34
NVRAM
35
ASIC
IMAGE FORMING UNIT
10
OPERATION UNIT
40
COMMUNICATION I/F
37

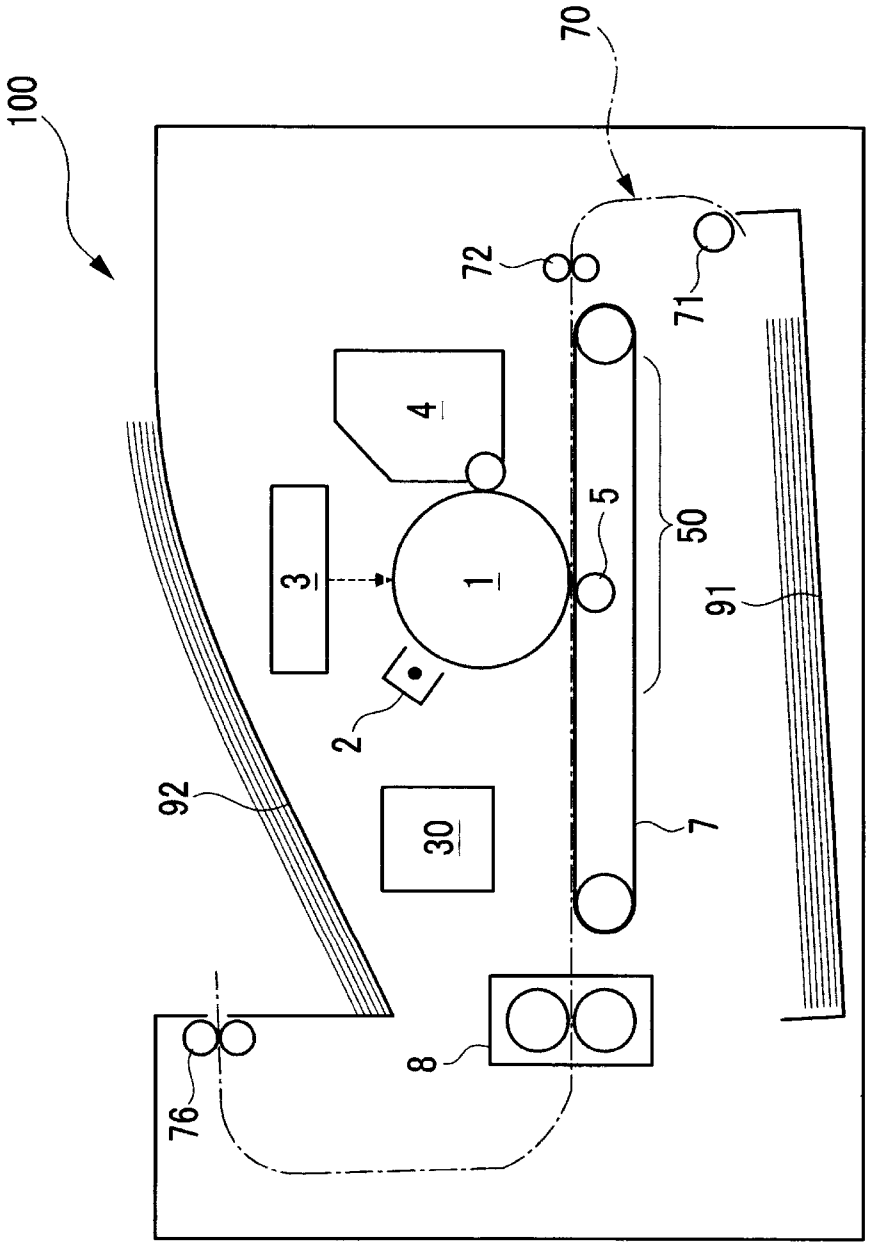


FIG. 2

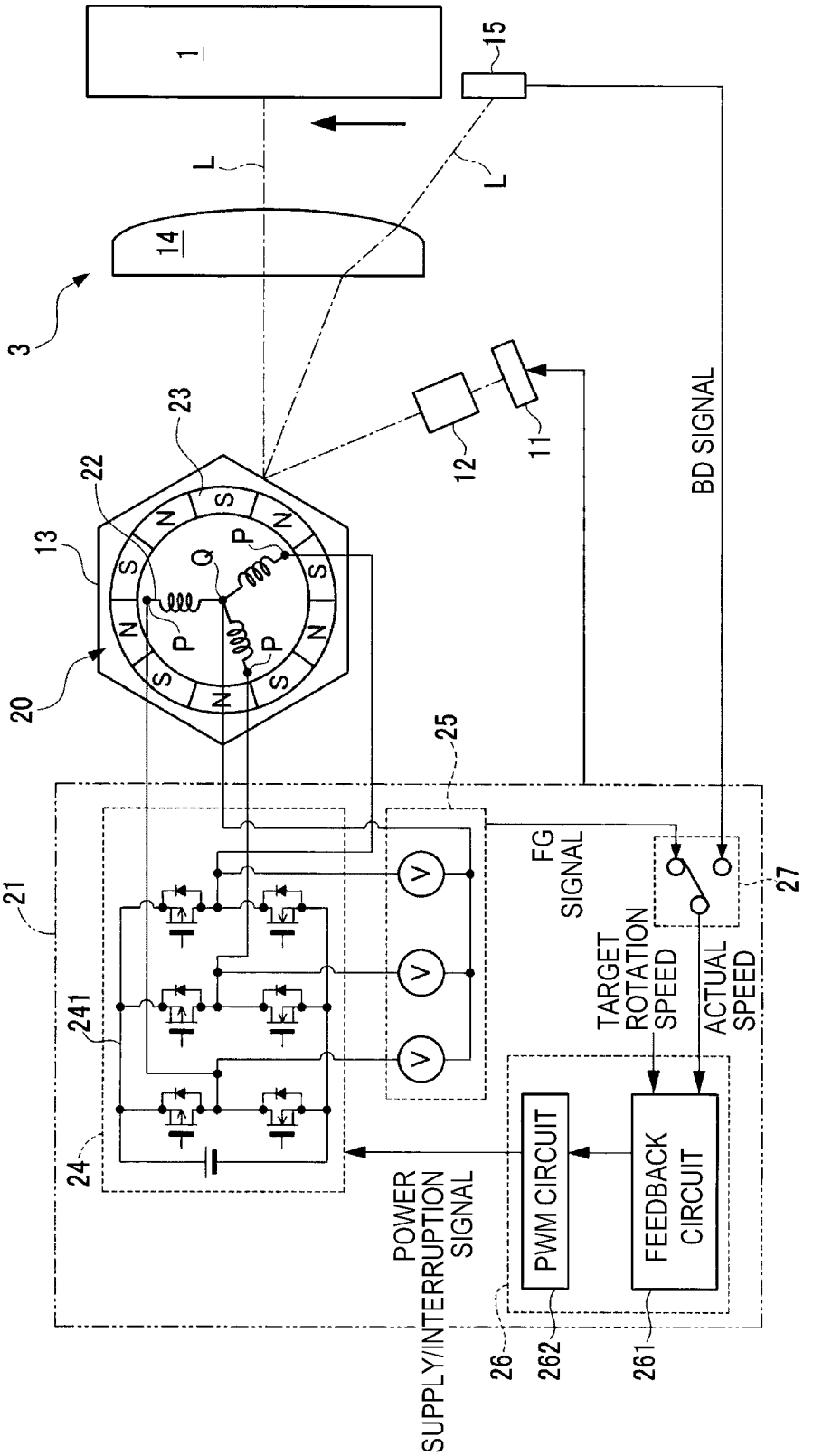

1
15
L
L'
14
3
23
22
13
20
12
11
BD SIGNAL
25
21
241
24
FG SIGNAL
27
TARGET ROTATION SPEED
ACTUAL SPEED
POWER SUPPLY/INTERRUPTION SIGNAL
PWM CIRCUIT
FEEDBACK CIRCUIT
26
262
261
N
S
P
Q
V

FIG. 3

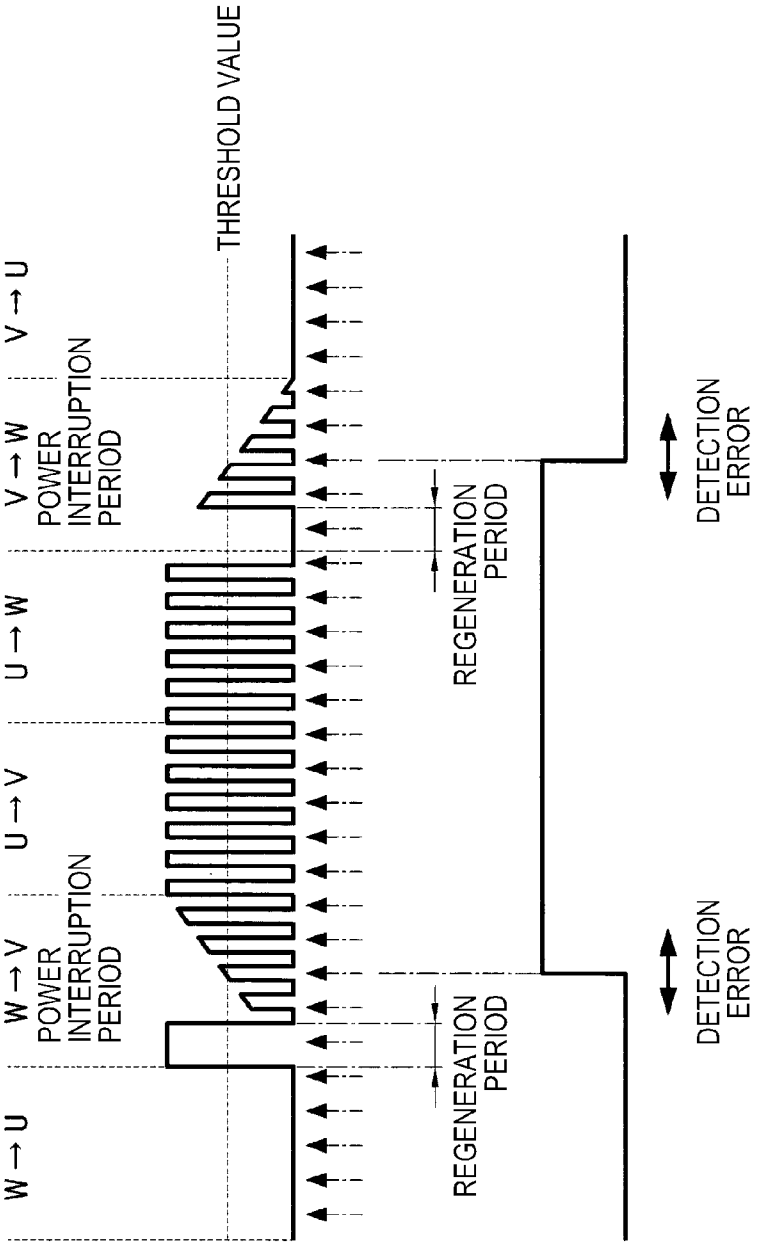

W → U
W → V POWER INTERRUPTION PERIOD
U → V
U → W
V → W POWER INTERRUPTION PERIOD
V → U
THRESHOLD VALUE
REGENERATION PERIOD
REGENERATION PERIOD
DETECTION ERROR
DETECTION ERROR
U-PHASE VOLTAGE
VOLTAGE DETECTION TIMING
FG SIGNAL

FIG. 4

FIG. 5

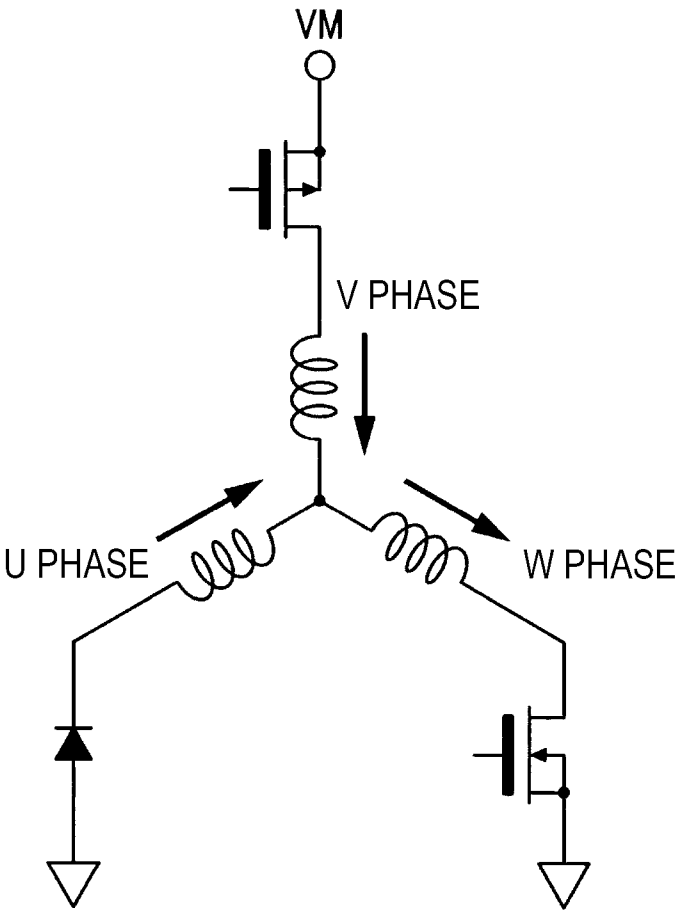


FIG. 6

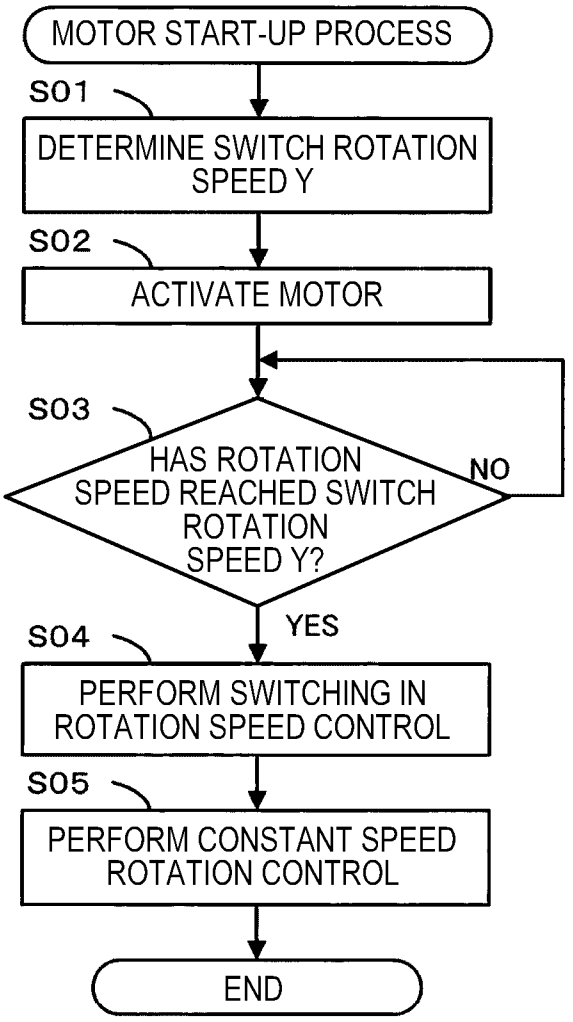

MOTOR START-UP PROCESS
S01
DETERMINE SWITCH ROTATION SPEED Y
S02
ACTIVATE MOTOR
S03
HAS ROTATION SPEED REACHED SWITCH ROTATION SPEED Y?
NO
YES
S04
PERFORM SWITCHING IN ROTATION SPEED CONTROL
S05
PERFORM CONSTANT SPEED ROTATION CONTROL
END

FIG. 7

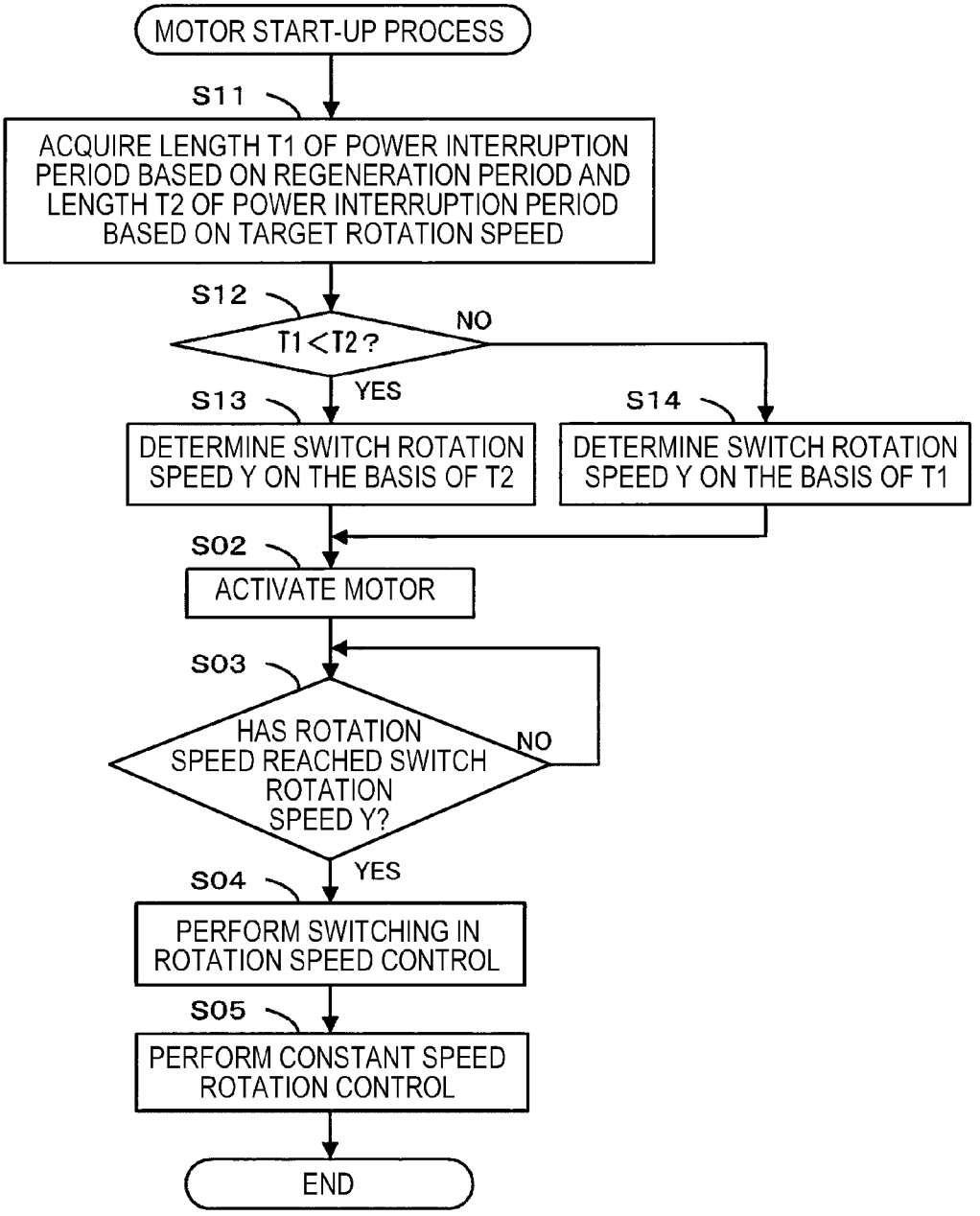

MOTOR START-UP PROCESS
S11
ACQUIRE LENGTH T1 OF POWER INTERRUPTION PERIOD BASED ON REGENERATION PERIOD AND LENGTH T2 OF POWER INTERRUPTION PERIOD BASED ON TARGET ROTATION SPEED
S12
T1<T2?
NO
YES
S13
DETERMINE SWITCH ROTATION SPEED Y ON THE BASIS OF T2
S14
DETERMINE SWITCH ROTATION SPEED Y ON THE BASIS OF T1
S02
ACTIVATE MOTOR
S03
HAS ROTATION SPEED REACHED SWITCH ROTATION SPEED Y?
NO
YES
S04
PERFORM SWITCHING IN ROTATION SPEED CONTROL
S05
PERFORM CONSTANT SPEED ROTATION CONTROL
END

IMAGE FORMING APPARATUS, METHOD OF CONTROLLING IMAGE FORMING APPARATUS, AND STORAGE MEDIUM

CROSS REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of Japanese Patent Application No. 2014-027321 filed on Feb. 17, 2014 the contents of which are incorporated herein by reference in its entirety.

BACKGROUND

The present disclosure relates to an image forming apparatus. More specifically, the present disclosure relates to an image forming apparatus which includes a polygon mirror for reflecting a light beam, and a brushless motor for rotating the rotational position, a method of controlling the image forming apparatus, and a storage medium.

Electrophotographic image forming apparatuses each of which includes a polygon mirror for reflecting a light beam and a brushless motor for rotating the polygon mirror has been put to practical use. As a technology for a brushless motor for acting as the driving source of a polygon mirror, a technology for performing control on rotation without using any Hall element is known.

As a document related to the technology for a brushless motor described above, there is Japanese Patent Application Laid-Open No. 2010-237622 for instance. Japanese Patent Application Laid-Open No. 2010-237622 discloses a technology in which the position of a rotor is specified on the basis of an induced voltage, and when rotation starts, rotation speed control is performed on the basis of the induced voltage, and after the rotation speed reaches a target rotation speed, rotation speed control is performed on the basis of a signal (a BD signal) which is obtained from a sensor which receives a light beam deflected by a polygon mirror.

SUMMARY

However, the above described technology according to the related art has the following problem. That is, in rotation speed control based on the induced voltage, as the rotation speed increases, the accuracy of induced-voltage detection decreases. Meanwhile, if rotation speed control based on the BD signal starts with a low rotation speed, a light beam moves on a photosensitive member, damage to the photosensitive member is feared.

An aspect of the present disclosure was made for solving the above described problem of the technology according to the related art. An object of the present disclosure is to provide a technology for performing switching in rotation speed control at appropriate timings in an image forming apparatus having a brushless motor for driving a polygon mirror.

The aspect of the present disclosure provides the following arrangements:

An image forming apparatus comprising:

a light source configured to emit a light beam;

a polygon mirror configured to reflect the light beam emitted from the light source;

a brushless motor including a plurality of coils, the brushless motor being configured to rotate the polygon mirror;

a light receiver configured to receive the light beam reflected by the polygon mirror; and

a controller configured to:

perform driving control on the brushless motor by switching between supply and interruption of power to each of the plurality of coils;

detect a value related to an induced voltage which is generated in at least one of the plurality of coils in a period of the interruption of the power during the brushless motor is rotated;

perform a phase switching process of referring to the detected value and performing phase switching based on a timing when the detected value reaches a reference value; and

in a start-up period when the brushless motor is started up from a stop state to a target rotation speed, perform a control switching process of performing switching from rotation speed control based on the induced voltage according to the phase switching process to rotation speed control based on the light receiving timing of the light beam by the light receiver in a specific range in which a length from a start timing of an interruption period of the power to a timing when the detected value reaches the reference value does not become shorter than a length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to the phase switching in the phase switching process.

A control method of an image forming apparatus which includes a light source configured to emit a light beam, a polygon mirror configured to reflect the light beam emitted from the light source, a brushless motor configured to rotate the polygon mirror, and a light receiver configured to receive the light beam reflected by the polygon mirror, the method comprising:

performing driving control on the brushless motor by switching between supply and interruption of power to each of the plurality of coils;

detecting a value related to an induced voltage which is generated in at least one of the plurality of coils in a period of the interruption of the power during the brushless motor is rotated;

performing a phase switching process of referring to the detected value and performing phase switching based on a timing when the detected value reaches a reference value; and

in a start-up period when the brushless motor is started up from a stop state to a target rotation speed, performing a control switching process of performing switching from rotation speed control based on the induced voltage according to the phase switching process to rotation speed control based on the light receiving timing of the light beam by the light receiver in a specific range in which a length from a start timing of an interruption period of the power to a timing when the detected value reaches the reference value does not become shorter than a length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to the phase switching in the phase switching process.

A non-transitory computer readable storage medium storing a program to be executed by an image forming apparatus which includes a light source configured to emit a light beam, a polygon mirror configured to reflect the light beam emitted from the light source, a brushless motor configured to rotate the polygon mirror, and a light receiver configured to receive the light beam reflected by the polygon mirror, the program causing the image forming apparatus to execute:

performing driving control on the brushless motor by switching between supply and interruption of power to each of the plurality of coils;

detecting a value related to an induced voltage which is generated in at least one of the plurality of coils in a period of the interruption of the power during the brushless motor is rotated;

performing a phase switching process of referring to the detected value and performing phase switching based on a timing when the detected value reaches a reference value; and

in a start-up period when the brushless motor is started up from a stop state to a target rotation speed, performing a control switching process of performing switching from rotation speed control based on the induced voltage according to the phase switching process to rotation speed control based on the light receiving timing of the light beam by the light receiver in a specific range in which a length from a start timing of an interruption period of the power to a timing when the detected value reaches the reference value does not become shorter than a length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to the phase switching in the phase switching process.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating the electrical configuration of a printer according to an embodiment.

FIG. **2** is a view illustrating the internal configuration of the printer shown in FIG. **1**.

FIG. **3** is a schematic diagram illustrating the configuration of an exposing unit.

FIG. **4** is a timing chart illustrating the waveforms of a U-phase voltage and an FG signal which is obtained from the U-phase voltage.

FIG. **5** is a view illustrating the concept of a regeneration current after immediately after switching to a current flowing from a V-phase coil to a W-phase coil.

FIG. **6** is a flow chart illustrating the procedure of a motor start-up process which is performed in the printer of the embodiment.

FIG. **7** is a flow chart illustrating the procedure of a motor start-up process which is performed in a printer of an application.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Hereinafter, a printing apparatus according to an illustrative embodiment will be described in detail with reference to the accompanying drawings. The present embodiment can be obtained by applying an aspect of the present disclosure to a printer for forming images in an electrophotographic manner.

As shown in FIG. **1**, a printer **100** of the present embodiment includes a controller **30**, which includes a CPU **31**, a ROM **32**, a RAM **33**, a non-volatile RAM (NVRAM) **34**, and an ASIC **35**. Also, the printer **100** includes an image forming unit **10** which forms images in an electrophotographic manner, an operation unit **40** which receives input operations from a user, and a communication interface **37** for connection with an external device. The image forming unit **10**, the operation unit **40**, and the communication interface **37** are controlled by the CPU **31**. Also, the controller **30** of FIG. **1** is the general term for hardware which is used for control of the printer **100**, and does not always mean a single piece of hardware actually existing in the printer **100**.

The ROM **32** stores firmware which is control programs for controlling the printer **100**, various options, initial values, etc. The RAM **33** is used as a work area into which various control programs are read, or as a storage area for temporarily storing image data.

According to control programs read from the ROM **32** and signals transmitted from a variety of sensors, the CPU **31** controls each component of the printer **100** while storing the process results in the RAM **33** or the NVRAM **34**. The CPU **31** is an example of a controller. Also, the controller **30** may be the controller, or the ASIC **35** may be the controller.

The communication interface **37** is hardware for enabling the printer to perform communication with other devices. Specific examples of the communication interface **37** include a network interface, a serial communication interface, and a parallel communication interface. The printer **100** can receive image data to be a print target in the image forming unit **10**, from an external device through the communication interface **37**.

The operation unit **40** is provided on the exterior of the printer **100**, and has a variety of buttons for receiving input operations from the user, and a touch panel for displaying messages and set contents. Examples of the variety of buttons include an execution button for inputting an instruction for starting image processing, and a cancellation button for inputting an instruction for canceling image processing. Also, the operation unit **40** receives a variety of inputs even by touch of user's finger on the touch panel.

Subsequently, the configuration of the image forming unit **10** of the printer **100** will be described with reference to FIG. **2**. The image forming unit **10** includes a process unit **50** which forms a toner image in an electrophotographic manner and transfers the toner image onto a paper sheet, an exposing unit **3** which irradiates the process unit **50** with light, a conveyance belt **7** which conveys the paper sheet to the transfer position of the process unit **50**, a fixing unit **8** which fixing the unfixed toner on the paper sheet, a paper feeding tray **91** where paper sheets before image transfer are mounted, and a paper discharge tray **92** where paper sheets after image transfer are mounted.

Also, inside the image forming unit **10**, a conveyance path **70** is formed substantially in a letter S shape as shown by an alternate long and short dash line in FIG. **2** such that a paper sheet stored in the paper feeding tray **91** positioned at the bottom is guided to the paper discharge tray **92** positioned at the upper portion, through a paper feeding roller **71**, resist rollers **72**, the process unit **50**, the fixing unit **8**, and paper discharging rollers **76**.

The process unit **50** includes a drum-like photosensitive member **1**, a charging unit **2** which uniformly charges the surface of the photosensitive member **1**, a developing unit **4** which develops an electrostatic latent image with toner, and a transfer unit **5** which transfers the toner image on the photosensitive member **1** onto a sheet. The photosensitive member **1** and the transfer unit **5** are disposed so as to be in contact with the conveyance belt **7**.

In the process unit **50**, the surface of the photosensitive member **1** is uniformly charged by the charging unit **2**. Thereafter, the photosensitive member **1** is irradiated with light from the exposing unit **3**, whereby an electrostatic latent image of an image to be formed on a paper sheet is formed on the surface of the photosensitive member **1**. Next, toner is supplied to the photosensitive member **1** through the

developing unit **4**. As a result, the electrostatic latent image on the photosensitive member **1** is visualized, that is, a toner image is formed.

The image forming unit **10** takes out paper sheets mounted on the paper feeding tray **91**, one by one, and conveys each paper sheet onto the conveyance belt **7**. Then, the toner image formed in the process unit **50** is transferred onto a paper sheet. Thereafter, the paper sheet having the toner image transferred thereon is conveyed to the fixing unit **8** where the toner image is thermally fixed on the paper sheet. Thereafter, the paper sheet is discharged onto the paper discharge tray **92**.

Subsequently, the configuration of the exposing unit **3** of the printer **100** will be described with reference to FIG. **3**. The exposing unit **3** includes a laser diode LD **11** which emits a laser beam L, a first lens unit **12**, a polygon mirror **13**, a second lens unit **14**, a beam detector (BD) **15**, a brushless motor **20**, and a control board **21**. The LD **11** is an example of a light source. The polygon mirror **13** is an example of a polygon mirror. The BD **15** is an example of a light receiver.

The first lens unit **12** is composed of a collimator lens, a cylindrical lens, or the like, and transmits the laser beam L emitted from the LD **11**, thereby irradiating the polygon mirror **13** with the laser beam L. The second lens unit **14** is composed of an f-O lens or a cylindrical lens, and transmits the laser beam L reflected from the polygon mirror **13**, thereby irradiating the photosensitive member **1** with the laser beam L.

The polygon mirror **13** is composed of six mirror surfaces, and is rotated by the brushless motor **20**. If the polygon mirror **13** rotates at a high speed, the laser beam L emitted from the LD **11** is periodically deflected, whereby scan lines are sequentially formed on the photosensitive member **1** through the second lens unit **14**.

The BD **15** is disposed so as to be able to receive a laser beam L deflected by the polygon mirror **13** before the laser beam L reaches the photosensitive member **1**. The BD **15** outputs a BD signal having an output value depending on whether a laser beam L has been received. The BD signal can be used to determine a writing timing of each scan line by the laser beam L. Also, the BD **15** may be disposed so as to be able to receive a laser beam L deflected by the polygon mirror **13** after the laser beam L reaches the photosensitive member **1**.

The brushless motor **20** is a 3-phase brushless DC motor, and includes a stator **22** having coils of a U phase, a V phase, and a W phase disposed thereon, and a rotor **23** having permanent magnets disposed therein. Also, in the brushless motor **20**, the coils are connected by star connection. The polygon mirror **13** rotates integrally with the rotor **23**.

The control board **21** includes a drive circuit **24** which performs driving control on the brushless motor **20**, a voltage detecting circuit **25** which detects an induced voltage generated in each coil of the brushless motor **20**, a speed adjusting circuit **26** which adjusts the rotation speed of the brushless motor **20**, and a switching circuit **27** which switches between actual-speed input signals to be input to the speed adjusting circuit **26**. The drive circuit **24** includes an inverter **241** which switches between supply and interruption of power to each coil of the brushless motor **20**, and the speed adjusting circuit **26** includes a feedback circuit **261** and a PWM circuit **262**. The circuits which are included in the control board **21** are composed of at least one ASIC. The control board **21** performs light emission control on the LD **11**, and rotation speed control on the brushless motor **20**, according to instructions from the CPU **31**.

Also, the printer **100** detects the position of the rotor **23** without using any position detecting element such as a Hall element. Specifically, the control board **21** detects the position of the rotor **23** on the basis of an induced voltage which is generated in each coil according to rotation of the rotor **23** relative to the stator **22**.

Now, detection of the position of the rotor **23** based on an induced voltage will be described. If the rotor **23** rotates, the S poles and N poles of the magnets alternately approach each coil constituting the stator **22**. As a result, the magnetic flux in each coil varies, whereby an induced voltage is generated in the corresponding coil. The waveform of the induced voltage periodically varies between a level in a case where an S pole is close to the corresponding coil and another level in a case where an N pole is close to the corresponding coil. Therefore, it is possible to detect the position of the rotor **23**, that is, what is the polarity of a magnet to the corresponding coil, by detecting the induced voltage.

In order to detect the induced voltage described above, the voltage detecting circuit **25** has three detectors corresponding to the coils, respectively. Each detector outputs a detection signal according to a potential difference between an end point P of a corresponding coil (an end point of a corresponding coil connected to the control board **21**) and the neutral point Q of the star connection. The control board **21** converts the detection signal received from each detector into a signal (hereinafter, referred to as a FG signal) whose level is inverted according to variation in the induced voltage, that is, change in the polarity of a magnet approaching a corresponding coil, by a converter or the like, and uses the FG signal.

FIG. **4** shows the waveforms of a U-phase detection voltage and a FG signal which is acquired from the U-phase detection voltage. As shown in FIG. **4**, if the detection voltage of the U-phase coil in a power interruption period becomes higher than a threshold value, the FG signal corresponding to the U phase varies from an OFF state to an ON state. Meanwhile, if the detection voltage of the U-phase coil in a power interruption period becomes lower than the threshold value, the FG signal corresponding to the U phase varies from the ON state to the OFF state. The voltage detecting circuit **25** detects the voltage value of each phase at a specific timing of a PWM period, and generates a FG signal of each phase.

On the occasion of controlling the rotation speed of the brushless motor **20**, the control board **21** can perform two kinds of rotation speed control, that is, rotation speed control based on the induced voltage generated in each coil, and rotation speed control based on the BD signal representing the light receiving timing of the laser beam L.

In a case of performing rotation speed control based on the induced voltage, the control board **21** uses the switching circuit **27** to switch a signal to be input to the speed adjusting circuit **26** into an FG signal. Then, the feedback circuit **261** of the speed adjusting circuit **26** outputs an adjusted value according to a rotation speed obtained by the FG signal, as an adjusted value relative to a target rotation speed. Thereafter, the PWM circuit **262** of the speed adjusting circuit **26** generates a power supply/interruption signal according to the adjusted value, and inputs the power supply/interruption signal to the drive circuit **24**. The drive circuit **24** controls the inverter **241** on the basis of the power supply/interruption signal such that the inverter switches the power supply/interruption state of each coil. As a result, the rotor **23** rotates, whereby the polygon mirror **13** is rotated.

Meanwhile, in a case of performing rotation speed control based on the BD signal, the control board **21** uses the switching circuit **27** to switch the signal to be input to the speed adjusting circuit **26** to the BD signal. Then, the LD **11** is turned on. Thereafter, the speed adjusting circuit **26** generates a power supply/interruption signal according to a rotation speed obtained by the BD signal, and inputs the power supply/interruption signal to the drive circuit **24**. The drive circuit **24** switches the power supply/interruption state of each coil on the basis of the power supply/interruption signal. Also, switching in rotation speed control will be described below.

Subsequently, rotation speed control on the brushless motor **20** will be described. In rotation speed control on the brushless motor **20**, the control board **21** determines a switch rotation speed to be a rotation speed for switching from rotation speed control based on the induced voltage to rotation speed control based on the BD signal. Thereafter, the control board **21** performs rotation speed control based on the induced voltage from when the brushless motor is activated to when the brushless motor reaches the switch rotation speed, and performs rotation speed control based on the BD signal after the brushless motor reaches the switch rotation speed.

In a case of rotating the brushless motor **20** for rotating the polygon mirror **13**, in a low-speed range, if the control board **21** performs rotation speed control based on the BD signal, the laser beam L moves on the photosensitive member **1** at a low speed, and thus damage to the photosensitive member **1** is feared. For this reason, in rotation speed control on the brushless motor **20**, during activation, the control board **21** performs rotation speed control based on the induced voltage.

Meanwhile, in a high-speed range, if rotation speed control based on the induced voltage is performed, jitter increases, and thus the accuracy of the FG signal decreases. As one of factors which increases jitter, a regeneration current which is generated when the power supply/interruption state of a coil is switched can be considered.

For example, as shown in FIG. **4**, if power supply to the U-phase coil is interrupted, in the power interruption period of the U phase, immediately after power supply is interrupted, there is a regeneration period when the regeneration current is generated. In the regeneration period, the voltage value is fixed, and thus it is impossible to normally detect the induced voltage. That is, immediately after start of the power interruption period, a period when it is impossible to detect the induced voltage occurs. The regeneration period is an example of a reference-disabled period.

The length of the above described regeneration period is obtained as follows. For example, immediately after switching to a current to flow from the V-phase coil to the W-phase coil, in the U-phase coil, a regeneration current having the opposite polarity is generated to flow to the neutral point as shown in FIG. **5**. If the coils of three phases have the same inductance L like in the brushless motor **20** of the present embodiment, the voltage of the neutral point becomes about ⅓ of a power supply voltage VM. Therefore, a voltage applied to the U-phase coil becomes about VM/3. Further, from V=LdI/dt, the current varies at V/3L. If it is assumed that a current (hereinafter, referred to as limited current I) having the upper limit current value flowed in coils when a current was applied to flow from the U-phase coil to the W-phase coil, a time when a current flowing in the U-phase coil becomes 0 becomes 3IL/V. This time becomes the length Treg of the regeneration period.

The above described length Treg (=3IL/V) of the regeneration period is a value irrelevant to the rotation speed of the brushless motor **20**. That is, even if the rotation speed increases, the length Treg of the regeneration period does not vary. Meanwhile, the length of one power interruption period shortens as the rotation speed increases. That is, as the rotation speed increases, the ratio of the regeneration period to the power interruption period tends to increase, and the accuracy of the FG signal tends to decrease.

First, the printer **100** activates the brushless motor **20** by rotation speed control based on the induced voltage. Then, even before the brushless motor **20** reaches the target rotation speed, the printer **100** performs switching to rotation speed control based on the BD signal before influence of the regeneration period becomes strong.

The procedure of a motor start-up process of implementing the above described rotation speed control will be described with reference to the flow chart of FIG. **6**. When the brushless motor **20** is in a stop state, if a command for activating the brushless motor **20** is input, the motor start-up process is performed by the CPU **31** or the control board **21**.

In the motor start-up process, first, in STEP **S01**, a switch rotation speed Y is determined as a rotation speed for switching from rotation speed control based on the induced voltage to rotation speed control based on the BD signal. The switch rotation speed Y is a speed different from the final target rotation speed. Further, the switch rotation speed Y is a rotation speed at which a length from the start timing of the power interruption period to a timing when the induced voltage reaches the threshold value does not become shorter than the length Treg of the regeneration period. Specifically, when the timing when the induced voltage reaches the threshold value is about the intermediate time of the power interruption period, the switch rotation speed Y needs only to be a rotation speed at which the length of one power interruption period does not become shorter than twice a length (Treg×2) which is twice the length Treg.

After the switch rotation speed Y is determined, in STEP **S02**, rotation of the brushless motor **20** is started. At this time, rotation speed control based on the induced voltage is performed. Next, in STEP **S03**, it is determined whether the current rotation speed of the brushless motor **20** exceeds the switch rotation speed Y. Until the rotation speed exceeds the switch rotation speed Y ("NO" in STEP **S03**), rotation speed control based on the induced voltage is kept.

If the rotation speed exceeds the switch rotation speed Y ("YES" in STEP **S03**), in STEP **S04**, switching to rotation speed control based on the BD signal is performed. That is, before it becomes easy to be influenced by the regeneration current, the LD **11** is turned on, and switching to rotation speed control based on the BD signal is performed.

After STEP **S04**, if the rotation speed reaches the target rotation speed, switching to constant speed rotation control is performed in STEP **505**. If the rotation speed reaches the target rotation speed, the start-up period of the brushless motor **20** finishes. After STEP **505**, the motor start-up process finishes. Also, in a case where the target rotation speed is lower than the switch rotation speed, switching to rotation speed control based on the BD signal may be performed at the timing when the rotation speed reaches the target rotation speed, and the motor start-up process may finish, or even after the rotation speed reaches the target rotation speed, rotation speed control based on the induced voltage may be kept, and the motor start-up process may finish.

Also, in the motor start-up process described above, if switching to rotation speed control based on the BD signal

is performed at the timing when the rotation speed exceeds the switch rotation speed Y, influence of the regeneration current is suppressed. However, at any timing before the brushless motor reaches a rotation speed at which influence of the regeneration period becomes strong (in the present embodiment, a rotation speed at which the length of one power interruption period becomes shorter than a length which is twice the length of the regeneration period), for example, at a timing before the rotation speed exceeds the switch rotation speed Y, the limited current I may be reduced. As described above, the length Treg of the regeneration period is determined by 3IL/V. Therefore, it is possible to reduce the regeneration period by reducing the limited current I. As a result, the ratio of the regeneration period to the power interruption period decreases, and thus it is possible to further reduce influence of the regeneration current.

Subsequently, a specific example of the switch rotation speed Y which is determined in STEP **S01** of the motor start-up process described above will be described.

In a case where the brushless motor **20** is a motor including an armature having 3 phases and 9 slots and a permanent magnet having 12 poles as a field pole, switching in energization phase is performed **36** (which is the least common multiple of 9 and 12) times for one period. That is, at a rotation speed X [rpm], the continuous energization time of one energization phase becomes as follows.

$$1/(X/60)/36=5/3X$$

For example, when the rotation speed X is 20000 [rpm], the continuous energization time of one energization phase becomes as follows.

$$1/(20000/60)/36=83.33[\mu s]$$

This continuous energization time has the same length as that of one power interruption period.

Also, for example, in control when the limited current is 2 A, if it is assumed that the inductance of the coils is 100 μH, and the power supply voltage VM is 24 V, the length Treg of the regeneration period becomes as follows.

$$Treg=3IL/V=3\times2[A]\times100[\mu H]/24[V]=25[\mu s]$$

Since the ideal detection timing of the induced voltage is the intermediate time of the power interruption period, if the regeneration time exceeds the intermediate time of the power interruption period, the detection accuracy is more likely to decrease. For this reason, as described above, a rotation speed at which the length of one power interruption period becomes Treg×2 is defined as a rotation speed at which the accuracy of detection of the induced voltage decreases. Therefore, if a configuration in which the above described limited current is 2 A, the inductance of the coils is 100 μH, and the power supply voltage is 24V is applied to the brushless motor **20** of the present embodiment, the rotation speed at which the accuracy of detection of the induced voltage decreases becomes as follows.

$$5/(25\ [\mu s]\times2)\times3=33333.33[rpm]$$

For this reason, a rotation speed lower than the corresponding rotation speed is determined as the switch rotation speed Y in STEP **S01**.

Subsequently, other factors which increase the jitter, that is, other factors which decrease the accuracy of the FG signal will be described. As factors which increase the jitter, in addition to the regeneration period, resolution shortage of the voltage detecting circuit **25** can be exemplified.

As shown in FIG. **4**, the voltage detecting circuit **25** detects the voltage value of each phase at a specific timing of a PWM period. For example, in a case where a PWM frequency is 125 kHz, the voltage detecting circuit **25** detects the voltage value of each coil at intervals of 8 μs.

In a case where the brushless motor **20** has the above described configuration (a motor including an armature having 3 phases and 9 slots and a permanent magnet having 12 poles as field poles), when the rotation speed is 20000 rpm, the power interruption period becomes 83.33 μs. Therefore, at the corresponding rotation speed, a detection error of (8 [μs]/83.33 [μs]×100)% is included. This detection error also causes the power interruption period to decrease as the rotation speed increases. Therefore, as the rotation speed increases, influence on the accuracy of the FG signal increases.

Also, when the switch rotation speed is determined in STEP **S01** of the motor start-up process, it is preferable to add the detection interval of the voltage detecting circuit **25**, that is, the period Tpwm of the PWM frequency. In the present embodiment, in STEP **S01**, the switch rotation speed is defined as a rotation speed at which the length of one power interruption period does not become shorter than Treg×2. Therefore, the switch rotation speed needs only to be a rotation speed at which the length of one power interruption period does not become shorter than Treg×2+Tpwm. Therefore, it is possible to suppress not only influence of the regeneration period but also influence of resolution shortage of the voltage detecting circuit **25**.

As described above, a decrease in the accuracy of the FG signal due to resolution shortage of the voltage detecting circuit **25** becomes more remarkable as the rotation speed increases. For this reason, a switch rotation speed based on the target rotation speed may be defined, and be compared with a switch rotation speed based on the regeneration period, and with reference to a lower speed of them, the switch rotation speed Y may be determined.

When the length of one power interruption period at the target rotation speed is denoted by Ttarg, and the frequency of the PWM frequency is denoted by Tpwm, the switch rotation speed based on the target rotation speed needs only to be defined as a rotation speed at which the length of one power interruption period does not become shorter than Ttarg+Tpwm.

Specifically, for example, in a case where the brushless motor **20** has the above described configuration (a motor including an armature having 3 phases and 9 slots and a permanent magnet having 12 poles as field poles), and the target rotation speed is 21000 rpm, a rotation speed at which it is estimated that the accuracy of the FG signal decreases becomes as follows.

$$5/(5/(3\times21000)+8\ [\mu s])\times3)=171693.3[rpm]$$

Also, in a case where the target rotation speed is 40000 rpm, a rotation speed at which it is estimated that the accuracy of the FG signal decreases becomes as follows.

$$5/(5/(3\times40000)+8\ [\mu s])\times3)=302013.4[rpm]$$

Before the brushless motor reaches the rotation speed at which it is estimated that the accuracy of the FG signal decreases, switching to rotation speed control based on the BD signal is performed.

FIG. **7** shows an operation of a motor start-up process using a switch rotation speed based on a target rotation speed. The motor start-up process of FIG. **7** is different from the motor start-up process of FIG. **6** in the procedure of determining the switch rotation speed.

In the motor start-up process of FIG. **7**, first, in STEP **S11**, the length T**1** of one power interruption period at a switch rotation speed based on the regeneration period, and the length T**2** of one power interruption period at a switch rotation speed based on the target rotation speed are acquired. Specifically, the lengths T**1** and T**2** of each power interruption period are defined as follow.

$$T1=\text{Treg}\times 2+Tpwm$$

$$T2=\text{Ttarg}+Tpwm$$

After STEP S**11**, in STEP S**12**, whether the length T**1** is shorter than length T**2** is determined. In a case where the length T**1** is shorter than the length T**2** ("YES" in STEP S**12**), in STEP S**13**, a rotation speed at which the length of the power interruption period becomes longer than the length T**2** is determined as the switch rotation speed Y of the present embodiment. Meanwhile, in a case where the length T**1** is not shorter than the length T**2** ("NO" in STEP S**12**), in STEP S**14**, a rotation speed at which the length of the power interruption period becomes longer than the length T**1** is determined as the switch rotation speed Y of the present embodiment.

After STEP S**13** or STEP S**14**, the motor start-up process proceeds to STEP S**12**, and the processes of STEP S**02** and the subsequent steps are identical to those of the motor start-up process of FIG. **6**. Like in the motor start-up process of FIG. **7**, since the switch rotation speed Y is determined by comparison between the switch rotation speed based on the target rotation speed and the switch rotation speed based on the regeneration period, it is possible to further suppress a decrease in the accuracy of the FG signal.

As described above in detail, in the printer **100** of the present embodiment, in control on the rotation speed of the brushless motor **20**, in the start-up period of the brushless motor **20**, rotation speed control based on the induced voltage is performed until the brushless motor reaches the switch rotation speed at which the rotation speed is unlikely to be influenced by the regeneration period, and after the brushless motor reaches the switch rotation speed, switching to rotation speed control based on the BD signal is performed. That is, before the brushless motor reaches the target rotation speed, whereby switching to constant speed rotation control is performed, the LD **11** is turned on and rotation speed control based on the BD signal is started. Therefore, before the detection accuracy decreases, switching in rotation speed control is performed. As a result, the rotation speed is stable. Also, in a low-speed range before switching in rotation speed control is performed, since rotation speed control based on the induced voltage is performed, damage to the photosensitive member **1** which is irradiated with the laser beam L is few.

The present embodiment is merely an example, and does not limit the present invention. Therefore, the present invention can be improved and modified in various forms without departing from the scope. For example, the image forming apparatus is not limited to a printer, but can be applied to any apparatuses having a printing function, such as a copy machine, a FAX, and a multi-function apparatus. Also, the printer **100** of the embodiment is a monochrome printer and has only one process unit **50**. However, the printer **100** may be a color printer having a plurality of process units.

Also, in the embodiment, on the occasion of acquiring the induced voltage generated in a coil, the potential difference between the end point P of the coil and the neutral point Q of the star connection is detected, that is, the induced voltage is detected. However, the induced voltage may not need to be detected. For example, while power is not supplied to the other coils, since the potential of the neutral point Q does not significantly vary, it is possible to estimate the induced voltage only with reference to the potential of the end point P of the coil. That is, instead of the induced voltage, a value related to the induced voltage may be referred to.

Also, in the motor start-up process of the embodiment, switching to rotation speed control based on the BD signal is performed when the rotation speed exceeds the switch rotation speed Y. However, switching to rotation speed control based on the BD signal may be performed when the brushless motor reaches the target rotation speed. In this case, when the rotation speed exceeds the switch rotation speed, it is needed to reduce the limited current, thereby suppressing influence of the regeneration current. That is, if a process of suppressing influence of the regeneration current by a method other than switching to rotation speed control based on the BD signal is performed when the rotation speed exceeds the switch rotation speed Y, switching to rotation speed control based on the BD signal does not need to be performed when the rotation speed exceeds the switch rotation speed Y.

Also, in the motor start-up process of the embodiment, the length Treg of the regeneration period is used to determine the switch rotation speed Y. However, the switch rotation speed Y may be determined on the basis of the target rotation speed without using the length Treg of the regeneration period. That is, the switch rotation speed may be set to a rotation speed at which the length of one power interruption period does not become shorter than Ttarg+Tpwm.

Also, in the embodiment, the upper limit value of the rotation speed is defined, for example, as a rotation speed at which the length of one power interruption period does not become shorter than a length (Treg×2) which is twice the length Treg, and in a rotation speed range satisfying the upper limit condition, it is considered that the condition of the switch rotation speed is satisfied. However, a lower limit value may be defined. The lower limit value may be a value at which damage to the photosensitive member **1** is allowed.

Also, the processes disclosed in the embodiment may be performed by a single CPU, a plurality of CPUs, hardware such as an ASIC, or a combination thereof. Further, the processes disclosed in the embodiment can be implemented in various forms such as a recording medium retaining a program for performing the processes, or a method.

The image forming apparatus which is disclosed in this specification has the polygon mirror whose driving source is the brushless motor, and performs rotation speed control based on an induced voltage which is generated in a coil of the brushless motor in a non-conducting period of the coil, with reference to a detected value related to the induced voltage. Further, in a start-up period of the brushless motor, the image forming apparatus performs switching from rotation speed control based on the induced voltage to rotation speed control based on the light receiving timing of the light beam such that a length from the start timing of a power interruption period of the coil to a timing when the detected value reaches the reference value is prevented from becoming shorter than the length of a reference-disabled period (regeneration period) in which the induced voltage cannot be detected due to a regeneration current.

That is, according to change in the power supply state, the regeneration current is generated in the coil. Therefore, at the time of acquiring the detected value related to the induced voltage in the power interruption period, in the power interruption period, a reference-disabled period in which the induced voltage cannot be detected due to a

regeneration current exists. The ratio of the reference-disabled period to the power interruption period increases as the rotation speed increases. Therefore, in the specific range in which it is difficult to be influenced by the reference-disabled period, the image forming apparatus which is disclosed in this specification performs switching from rotation speed control based on the induced voltage to rotation speed control based on the light receiving timing of the light beam. Therefore, before the detection accuracy decreases, switching in rotation speed control is performed. As a result, the rotation speed is stable.

If the reference-disabled period is specified on the basis of the above described three factors, it is possible to control the switching timing with high accuracy.

In a case of referring to the detected value related to the induced voltage on the basis of the period of the PWM frequency, there is a difference between a timing when the detected value exceeds the reference value and a timing when the detected value is referred to. For this reason, if the period of the PWM frequency is included in the requirements, it is possible to expect more accurate control.

In a case of referring to the detected value related to the induced voltage on the basis of the period of the PWM frequency, there is a difference between a timing when the detected value exceeds the reference value and a timing when the detected value is referred to. For this reason, if the period of the PWM frequency is included in the requirements, it is possible to expect more accurate control.

The power interruption period at the target rotation speed decreases as the target rotation speed increases. Therefore, it is possible to expect more stable rotation control by changing the requirements of the specific range according to the target rotation speed.

If the limited current is reduced (that is, the reference-disabled period due to the regeneration current is reduced) before switching to rotation speed control based on the BD signal, it is possible to further stabilize rotation speed control until switching to rotation speed control based on the BD signal is performed.

If the light beam is emitted from a timing before switching in rotation speed control, that is, from a timing before the rotation speed reaches the target rotation speed, it is possible to surely perform switching to rotation speed control based on the light receiving timing of the light beam.

Also, in this specification, there is disclosed an image forming apparatus which includes a light source that emits a light beam, a polygon mirror that reflects the light beam emitted from the light source, a brushless motor that rotates the polygon mirror, a light receiver that receives the light beam reflected by the polygon mirror, and a controller. In this image forming apparatus, the controller performs a phase switching process of referring to a detected value related to an induced voltage which is generated in a coil of the brushless motor in a power interruption period of the corresponding coil during rotation of the brushless motor and performing phase switching on the basis of a timing when the detected value reaches a reference value. Further, in a specific range which is a rotation speed range which is in a start-up period when the brushless motor is started up from a stop state to a target rotation speed and in which a length from the start timing of a power interruption period to a timing when the detected value reaches the reference value does not become shorter than the length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to phase switching in the phase switching process, the controller performs a current decreasing process of decreasing the upper limit value of a current which flows in the coil of the brushless motor.

Also, in this specification, there is disclosed an image forming apparatus which includes a light source that emits a light beam, a polygon mirror that reflects the light beam emitted from the light source, a brushless motor that is rotated under PWM control, thereby rotating the polygon mirror, a light receiver that receives the light beam reflected by the polygon mirror, and a controller. In this image forming apparatus, the controller performs a phase switching process of referring to a detected value related to an induced voltage which is generated in a coil of the brushless motor in a power interruption period of the corresponding coil during rotation of the brushless motor, with reference to the period of a PWM frequency, and performing phase switching on the basis of a timing when the detected value reaches a reference value. Further, in a specific range which is a rotation speed range which is in a start-up period when the brushless motor is started up from a stop state to a target rotation speed and in which one power interruption period is longer than a time which is the sum of the period of the PWM frequency and the length of one reference-disabled period at the target rotation speed, the controller performs a control switching process of performing switching from rotation speed control based on the induced voltage according to the phase switching process to rotation speed control based on the light receiving timing of the light beam by the light receiver.

Also, control methods and computer programs for implementing the functions of the above described image forming apparatus, and computer-readable storage media retaining the corresponding computer programs also are new and useful.

According to the present disclosure, a technology for performing switching in rotation speed control at appropriate timings in an image forming apparatus having a brushless motor for driving a polygon mirror is implemented.

What is claimed is:

1. An image forming apparatus comprising:

a light source configured to emit a light beam;

a polygon mirror configured to reflect the light beam emitted from the light source;

a brushless motor including a plurality of coils, the brushless motor being configured to rotate the polygon mirror;

a light receiver configured to receive the light beam reflected by the polygon mirror; and

a controller configured to:

perform driving control on the brushless motor by switching between supply and interruption of power to each of the plurality of coils;

detect a value related to an induced voltage which is generated in at least one of the plurality of coils in a period of the interruption of the power during the brushless motor is rotated;

perform a first control of referring to the detected value and performing phase switching based on a timing when the detected value reaches a reference value; and

in a start-up period when the brushless motor is started up from a stop state, perform a second control of performing switching from first rotation speed control based on the induced voltage according to the first control to second rotation speed control based on the light receiving timing of the light beam by the light receiver in a specific range in which a length from a start timing of an interruption period of the power to a timing when the

detected value reaches the reference value does not become shorter than a length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to the phase switching in the first control, the second rotation speed control operable without regard to the induced voltage;

after the second control performs switching from the first rotation speed control to the second rotation speed control, perform the second rotation speed control and not the first rotation speed control to increase a rotation speed of the polygon mirror to reach a target rotation speed; and

when the rotation speed of the polygon mirror reaches the target rotation speed, perform a constant speed control based on the light receiving timing of the light beam by the light receiver, and

wherein the specific range is a range of a rotation speed slower than the target rotation speed.

2. The image forming apparatus according to claim **1**, wherein

the length of the reference-disabled period is specified based on an upper limit value of a current value which flows in the coil of the brushless motor, a voltage value which is applied to the coil of the brushless motor, and inductance of the coil of the brushless motor.

3. The image forming apparatus according to claim **1**, wherein

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of the period of a PWM frequency, and

the specific range is further defined by a condition in which the interruption period is longer than a time which is the sum of a length which is twice the length of the reference-disabled period and the period of the PWM frequency.

4. The image forming apparatus according to claim **1**, wherein:

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of a period of a PWM frequency, and

the specific range is further defined by a condition in which the interruption period is longer than a time which is the sum of a period of the PWM frequency and the length of the one interruption period at the target rotation speed.

5. The image forming apparatus according to claim **1**, wherein:

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of the period of a PWM frequency, and

the specific range is further defined by a condition in which the one interruption period is longer than a time which is the sum of a length which is twice the length of the reference-disabled period and the period of the PWM frequency and is longer than a time which is the sum of the period of the PWM frequency and the length of the one interruption period at the target rotation speed.

6. The image forming apparatus according to claim **1**, wherein in the specific range, the controller performs a third control of decreasing an upper limit value of a current which flows in one of the plurality of coils.

7. The image forming apparatus according to claim **1**, wherein

before switching from the first rotation speed control to the second rotation speed control, the controller performs a fourth control of controlling the light source to emit the light beam.

8. The image forming apparatus according to claim **1**, wherein the brushless motor is a 3-phase brushless DC motor, and the reference disabled period is defined by 3IL/V where I is a limit current flowed in coils of the 3-phase brushless DC motor, V is a voltage applied to the coils, and L is an inductance of the coils.

9. A control method of an image forming apparatus which includes a light source configured to emit a light beam, a polygon mirror configured to reflect the light beam emitted from the light source, a brushless motor configured to rotate the polygon mirror, and a light receiver configured to receive the light beam reflected by the polygon mirror, the method comprising:

performing driving control on the brushless motor by switching between supply and interruption of power to each of the plurality of coils;

detecting a value related to an induced voltage which is generated in at least one of the plurality of coils in a period of the interruption of the power during the brushless motor is rotated;

performing a first control of referring to the detected value and performing phase switching based on a timing when the detected value reaches a reference value; and

in a start-up period when the brushless motor is started up from a stop state, performing a second control of performing switching from first rotation speed control based on the induced voltage according to the first control to second rotation speed control based on the light receiving timing of the light beam by the light receiver in a specific range in which a length from a start timing of an interruption period of the power to a timing when the detected value reaches the reference value does not become shorter than a length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to the phase switching in the first control, the second rotation speed control operable without regard to the induced voltage;

after the second control performs switching from the first rotation speed control to the second rotation speed control, performing the second rotation speed control and not the first rotation speed control to increase a rotation speed of the polygon mirror to reach a target rotation speed; and

when the rotation speed of the polygon mirror reaches the target rotation speed, performing a constant speed control based on the light receiving timing of the light beam by the light receiver, and

wherein the specific range is a range of a rotation speed slower than the target rotation speed.

10. The control method according to claim **9**, wherein

the length of the reference-disabled period is specified based on an upper limit value of a current value which flows in the coil of the brushless motor, a voltage value which is applied to the coil of the brushless motor, and inductance of the coil of the brushless motor.

11. The control method according to claim **9**, wherein

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of the period of a PWM frequency, and

the specific range is further defined by a condition in which the interruption period is longer than a time which is the sum of a length which is twice the length of the reference-disabled period and the period of the PWM frequency.

12. The control method according to claim **9**, wherein:

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of a period of a PWM frequency, and

the specific range is further defined by a condition in which the interruption period is longer than a time which is the sum of a period of the PWM frequency and the length of the one interruption period at the target rotation speed.

13. The control method according to claim **9**, wherein:

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of the period of a PWM frequency, and

the specific range is further defined by a condition in which the one interruption period is longer than a time which is the sum of a length which is twice the length of the reference-disabled period and the period of the PWM frequency and is longer than a time which is the sum of the period of the PWM frequency and the length of the one interruption period at the target rotation speed.

14. The control method according to claim **9**, wherein in the specific range, the controller performs a third control of decreasing an upper limit value of a current which flows in one of the plurality of coils.

15. The control method according to claim **9**, wherein

before switching from the first rotation speed control to the second rotation speed control, the controller performs a fourth control of controlling the light source to emit the light beam.

16. The control method according to claim **9**, wherein the brushless motor is a 3-phase brushless DC motor, and the reference-disabled period is defined by 3IL/V where I is a limit current flowed in coils of the 3-phase brushless DC motor, V is a voltage applied to the coils, and L is an inductance of the coils.

17. A non-transitory computer readable storage medium storing a program to be executed by an image forming apparatus which includes a light source configured to emit a light beam, a polygon mirror configured to reflect the light beam emitted from the light source, a brushless motor configured to rotate the polygon mirror, and a light receiver configured to receive the light beam reflected by the polygon mirror, the program causing the image forming apparatus to execute:

performing driving control on the brushless motor by switching between supply and interruption of power to each of the plurality of coils;

detecting a value related to an induced voltage which is generated in at least one of the plurality of coils in a period of the interruption of the power during the brushless motor is rotated;

performing a first control of referring to the detected value and performing phase switching based on a timing when the detected value reaches a reference value; and

in a start-up period when the brushless motor is started up from a stop state to a target rotation speed, performing a second control of performing switching from first rotation speed control based on the induced voltage according to the first control to second rotation speed control based on the light receiving timing of the light beam by the light receiver in a specific range in which a length from a start timing of an interruption period of the power to a timing when the detected value reaches the reference value does not become shorter than a length of a reference-disabled period in which the induced voltage cannot be detected due to a regeneration current attributable to the phase switching in the first control, the second rotation speed control operable without regard to the induced voltage;

after the second control performs switching from the first rotation speed control to the second rotation speed control, performing the second rotation speed control and not the first rotation speed control to increase a rotation speed of the polygon mirror to reach a target rotation speed; and

when the rotation speed of the polygon mirror reaches the target rotation speed, performing a constant speed control based on the light receiving timing of the light beam by the light receiver, and

wherein the specific range is a range of a rotation speed slower than the target rotation speed.

18. The non-transitory computer readable storage medium according to claim **17**, wherein

the length of the reference-disabled period is specified based on an upper limit value of a current value which flows in the coil of the brushless motor, a voltage value which is applied to the coil of the brushless motor, and inductance of the coil of the brushless motor.

19. The non-transitory computer readable storage medium according to claim **17**, wherein

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of the period of a PWM frequency, and

the specific range is further defined by a condition in which the interruption period is longer than a time which is the sum of a length which is twice the length of the reference-disabled period and the period of the PWM frequency.

20. The non-transitory computer readable storage medium according to claim **17**, wherein:

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of a period of a PWM frequency, and

the specific range is further defined by a condition in which the interruption period is longer than a time which is the sum of a period of the PWM frequency and the length of the one interruption period at the target rotation speed.

21. The non-transitory computer readable storage medium according to claim **17**, wherein:

the brushless motor is rotated under PWM control, and

in the first control, the controller refers to the detected value on the basis of the period of a PWM frequency, and

the specific range is further defined by a condition in which the one interruption period is longer than a time which is the sum of a length which is twice the length of the reference-disabled period and the period of the PWM frequency and is longer than a time which is the sum of the period of the PWM frequency and the length of the one interruption period at the target rotation speed.

22. The non-transitory computer readable storage medium according to claim **17**, wherein in the specific range, the

controller performs a third control of decreasing an upper limit value of a current which flows in one of the plurality of coils.

23. The non-transitory computer readable storage medium according to claim **17**, wherein the brushless motor is a 3-phase brushless DC motor, and the reference-disabled period is defined by 3IL/V where I is a limit current flowed in coils of the 3-phase brushless DC motor, V is a voltage applied to the coils, and L is an inductance of the coils.

* * * * *